

SUMMARY OF THE LATIN AMERICAN WORKSHOP ON FUNDAMENTAL INTERACTIONS*

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Abstract

Summary of the Latin American Workshop on the Fundamental Interactions held at the Physics Department of the Universidad de Buenos Aires from 26 to 30 July 2004.

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Introduction

Simultaneously with the Sixth J.J. Giambiagi Winter School of Physics ¹ organized by the Physics Department of the Buenos Aires University, a new edition of the Latin American Workshop on the Fundamental Interactions took place. The workshop was organized in association with the Latin American Network on Phenomenology of the Fundamental Interactions. As in previous editions of the workshop, it aimed to tighten the already existing links between the High Energy Physics community of the region. The workshop offered the possibility of presenting recent results and research in progress to many members of the community, both young scientists and more experienced researchers.

There were over 30 contributions presented by participants coming from 19 institutions from 9 different countries. These figures speak by themselves about the impact of the meeting.

At a first sight one can divide the mentioned contributions among 9 different topics, namely: Quantum Chromodynamics with 6 contributions, Beyond the Standard Model, Hadrons and Cosmic Rays Physics with 4, Neutrino Physics, CP Violation and Chiral Models with 2, Astroparticles with 1 contribution and Strings and Field Theory with 7. This distribution of topics provides, in some sense, a panorama of the main interest of the research activities in progress in the region.

Before entering in a more detailed analysis of the work presented during the workshop, we would like to stress not only the high level of the presentations but the actual interest of the subjects covered. No doubt, all the topics treated are of real present interest to the international community. The results discussed have been recently presented in renowned international publications or they will be published in the near future. Another point that has to be emphatically remarked is the young condition of the almost two thirds of the active participants in the workshop. All these details allow one to ensure that a promising future can be expected for the phenomenology of the fundamental interactions in the region.

Summary Report

Quantum Chromodynamics

The photon structure function: new parameterizations for the parton content of the photon ²

New NLO parameterizations for the parton content of the real photon were presented. These parameterizations were obtained performing fits to all the available data for the Photon Structure Function with $Q^2 > 1 \text{ GeV}^2$. Special attention was given to the way of dealing with the heavy quark contributions and various approaches were compared.

Single spin asymmetries ³

Among the very interesting developments of spin physics in last years, the azimuthal asymmetry found originally by the Hermes collaboration in pion electroproduction is particularly outstanding. The importance of these measurements was stressed on the basis that they represent a new class of measurements of spin processes, and act as a filter for exotic parton distributions such as transversity.

Dilepton p_T distribution through the Color Glass Condensate ⁴

The dilepton production in proton-nucleus collisions at the forward region was investigated using the Color Glass Condensate, a saturated dense system of partons, particularly gluons. In the high energy kinematical limit the saturation of the gluon density is required by unitarity. It was found that the lepton pair is a most suitable observable to analyze this saturated regime. It was shown that saturation effects are large in the transverse momentum distribution (p_T) of the dileptons, particularly in the low p_T region. The calculations were performed for the energies of interest at RHIC ($\sqrt{s} = 350 \text{ GeV}$) and LHC ($\sqrt{s} = 8800 \text{ GeV}$).

Consistency of NLO global analysis ⁵

A detailed study of consistency between different sets of polarized deep inelastic scattering data and theory was presented. The analysis followed the criteria proposed by Collins and Pumplin. It was also discussed the implementation of the double Mellin transform into the global fit, in order to circumvent the extremely time-consuming convolution integrals involved in the standard calculation.

High density Quantum Chromodynamics through hard probes ⁶

Investigations on the signature of the Color Glass Condensate, saturated dense system of partons (gluons), were presented. The signature of these non-linear effects in QCD were analyzed by considering appropriate observables carrying suitable information. Specific distributions of the observables of the saturation effects, in particular the transverse momentum of the dilepton produced in the heavy ion colliders, were analyzed.

Meson production in ultrarelativistic heavy ion collisions ⁷

A critical analysis of the signature of deconfined strongly interacting matter, the Quark-Gluon Plasma (QGP), was presented. As the QGP can only be detected indirectly, one of the possible signatures is the quarkonium suppression, in particular the J/Psi suppression. It was discussed that mesons are not only affected by the formation of the deconfined phase because other possible contributions to the suppression are present. In the initial state, effects as shadowing, partonic energy loss before the hard interaction and the parton recombination, due to the high partonic density, were taken into account. In the final state, rescattering effects and mechanisms associated with the high density produced in the collisions were considered. Hadron production at RHIC was analyzed in order to determine the magnitude of the initial state effects present in the corresponding kinematical regime.

Beyond the Standard Model

Double charged bileptons in $3 - 3 - 1$ models ⁸

The production of bileptons within the model with $SU(3) \otimes SU(3) \otimes U(1)$ gauge symmetry was studied. This model predicts single and double charged bileptons and exotic quarks carrying charges of $-4/3$ and $5/3$ units of the positron charge. The analysis of the phenomenological consequences of the model was done in connection with $e^+ e^-$ and pp collisions at future linear colliders and LHC.

Study of new gauge boson properties at ATLAS ⁹

A possible signal and properties of a new neutral gauge boson Z' , in a mass range $800 - 2000 \text{ GeV}$, were investigated in the channel $\text{proton} + \text{proton} \rightarrow \mu\text{on} + \mu\text{on} + \text{photon}$, at LHC for CM energy of 14 TeV and a luminosity of $100/\text{fb}$. CompHep, PYTHIA and detector simulation packages were used for the calculation. The total cross-sections, mass distributions, transversal momentum and asymmetry were analyzed in order to identify and distinguish the two minimal left-right mirror and left-right symmetric models. The preliminary simulation results have shown that the Z' could be observed in the above channel and its properties determined by fitting some muon distributions.

Finite temperature behavior of an extended model with a triplet Higgs boson ¹⁰

The finite temperature effective potential of an extension of the Standard Model with an extra triplet Higgs boson was computed. Constraints on the parameters of the model consistent with precision electroweak measurements and cosmology were determined.

Spontaneous parity breaking and fermion masses ¹¹

A $SU(2)_L \otimes SU(2)_R \otimes U(1)$ left-right symmetric model for elementary particles was presented and its connection with the fermion mass spectrum was considered. The model includes new mirror fermions and a minimal set of Higgs particles and can accommodate a consistent pattern for charged and neutral fermion masses as well as neutrino oscillations. The connection between the left and right sectors is done through the neutral vector gauge boson Z and a new heavier boson Z' .

Hadrons

A new signature for glueballs ¹²

An effective glueball-glueball interaction Hamiltonian in the context of a constituent gluon model, involving explicit gluon degrees of freedom was derived by means of a mapping technique (the Fock-Tani formalism). The calculation was focused on the interacting $J^{PC} = 0^{++}$ state. The 0^{++} resonance, being an isospin zero state can be either represented as a $s\bar{s}$ bound state or a glueball with the same quantum numbers. The different values of the corresponding cross-section were proposed as a mean for distinguishing between both descriptions.

The tower structure of $L=1$ excited baryons and their strong decays ¹³

In the large N_c limit, the mass spectrum of the $L = 1$ orbitally excited baryons N^*, Δ^* is shown to have a very simple structure, with states degenerate in pairs of spins $J = (1/2, 3/2), (3/2, 5/2)$, corresponding to irreducible representations (towers) of the contracted $SU(4)_c$ symmetry group. The mixing angles were completely determined in this limit. The $1/N_c$ corrections were computed, pointing out a four-fold ambiguity in the correspondence of the observed baryons with the large N_c states. The leading order predictions for the strong decays were also discussed.

Annihilation amplitudes and factorization in $B^{+/-}$ to $\phi K^{*+/-}$ ¹⁴

The decay $B^{+/-}$ to $\phi K^{*+/-}$, followed by the decay of the outgoing vector mesons into two pseudoscalars was studied. The analysis of angular distributions of the decay products was shown to provide useful information about the annihilation contributions and possible tests of factorization.

Pion nucleon scattering and pion photoproduction. Dynamical models

¹⁵

The phenomenological treatment of unstable particles in reactions generated by hadron and electromagnetic probes on the nucleon was presented. As a consequence, a consistent model that respects gauge invariance, Lorentz invariance and invariance under contact transformations in the spin-3/2 fields was obtained.

Cosmic Rays Physics

Double extensive air shower induced by ultra-high energy cosmic tau-neutrino¹⁶

The role of ultra-high energy cosmic neutrinos in explaining the origin of cosmic rays with energies beyond the GZK limit of few times $10^{19} eV$ was considered. As neutrinos hardly interact with cosmic microwave background or intergalactic magnetic fields, they keep their original energy and direction of propagation. When neutrino flavor oscillations are taken into consideration the flavor proportion is $\nu_e : \nu_\mu : \nu_\tau = 1 : 1 : 1$ instead of $\nu_e : \nu_\mu : \nu_\tau = 1 : 2 : 0$ as expected a priori. On this basis, the possibility of detecting ultra-high energy cosmic tau-neutrinos was analyzed by means of a process involving a double extensive air shower, the so-called Double-Bang Phenomenon. In this process a primary tau-neutrino interacts with an atmospheric quark creating a first hadronic shower and a tau-lepton, which subsequently decays creating a second cascade. As the number of these events strongly depends on the flux of tau-neutrinos arriving at the Earth's atmosphere, they can be used to test theoretical models for the production of ultra-high energy tau-neutrinos. The potential of the fluorescence detector of the Pierre Auger Observatory to observe Double-Bang events was studied.

Revision of the neutrinos oscillation probability in the supernovae¹⁷

The analytical expression of the oscillations probability in the supernovae and the use of a simple analytical prescription was reviewed. A comparison with the numerical results which are obtained from the solution of the evolution equation was also performed.

Absolute calibration of Auger fluorescence detector¹⁸

The description of the calibrated light device called Drum, designed and used at the Fluorescence Detector of the Pierre Auger Observatory was presented. It is being used for the absolute end-to-end calibration of each of its telescopes. The Drum is a 2.5m diameter device that simulates a far away point source of UV light pulses (shower like) that can be mounted on the aperture of any Fluorescence Detector telescopes of the Observatory. The instrument can be taken as a black-box because when injecting a known input flux and measuring its response under normal operation conditions, the calibration constant can be calculated for each of its pixels (photo-multipliers).

Calibration of the Pierre Auger surface detectors¹⁹

The remoteness and difficulty to access each detector of the ground array of the Pierre Auger Observatory that consists of 1600 Water Cerenkov Detectors deployed over 3000 km² at Pampa Amarilla, near Malarge, in Mendoza, Argentina, imposed an automatic remote calibration procedure that was designed. It was decided that the main parameter to be determined is the average charge deposited by central muons crossing the water volume vertically.

Neutrino Physics

Neutrino factories and the degeneracies in the measurement of neutrino oscillation parameters²⁰

The future neutrino factories and their characteristics for measuring neutrino oscillation parameters contained in the Pontecorvo-Maki-Nakagawa-Sakata mixing matrix were reviewed. The degeneracies in neutrino oscillation parameters was analyzed, making a quantitative analysis to find out how to solve these degeneracies in neutrino factories. To this end, the so called "Golden" and "Silver" channels, combining the effect of measuring particles and antiparticles in the same experiment were considered.

Neutrino absorption tomography of the Earth²¹

The passage of Ultra High Energy neutrinos through the Earth was studied in order to perform an absorption tomography of its inner structure. The Earth's density was reconstructed using the 2-d Radon transform considering neutral current regeneration through the complete transport equation and the results were compared with the ones obtained with the effective cross section. It was found that the transport equation approach is more accurate than the effective cross section approach especially for flat initial spectra, and that the recovered density presents a percentage uncertainty less than two times the uncertainty in the flux.

CP Violation

Correlated B-meson decays into CP-eigenstates²²

It was shown that in the B-meson correlated decay experiment the decays to $J/\Psi K_{SL}$ can be used to place CP-tags. This theoretical tool allows the correlated decays analysis of Flavor-Flavor and Flavor-CP to be completed with the decays CP-Flavor and CP-CP. These results show a way to measure Standard Model parameters, as for instance $\sin(2\beta)$, and through CP Δt asymmetries, an observable can be introduced to obtain $\Delta\Gamma$ linearly.

CP and T Trajectory diagrams for a unified graphical representation in context of neutrino oscillations²³

The CP trajectory diagrams, introduced to demonstrate the difference between the intrinsic CP violating effects and those induced by matter for neutrino oscillation were analyzed.

Chiral Models

Two flavor superconductivity in nonlocal chiral quark models ²⁴

A relativistic quark model with non-local quark-antiquark and quark-quark interactions at finite temperature and density was studied. The structure of the corresponding phase diagram was analyzed and the competition between the chiral and two superconducting phases discussed.

Properties of light pseudoscalar mesons in a nonlocal chiral quark model ²⁵

The predictions for masses and decay constants of light pseudoscalar mesons in a nonlocal $SU(3)$ chiral quark model were presented. The results found are in reasonable agreement with the corresponding empirical values, in particular in the case of the ratio f_K/f_π , the decay $\pi^0 \rightarrow \gamma\gamma$ and the observed phenomenology in the $\eta-\eta'$ sector. The $\eta-\eta'$ mixing was described by introducing two mixing angles which turn out to be significantly different from each other.

Astroparticles

Pulsar velocities and active-sterile neutrino oscillations ²⁶

Active-sterile neutrino transformations in a magnetized protoneutron star were described on the basis of a spherical resonance layer for neutrinos moving in different directions. The asymmetry in the momentum taken away by neutrinos was expressed in terms of the thickness of the resonance shell, which depends on the intensity of the magnetic field. The required pulsar kicks could be obtained with the magnetic fields expected in the interior of a protoneutron star, for sterile neutrino masses of the order of keV and small mixing angles.

Strings and Field Theory

Composite states in string theory: an holographic view ²⁷

The contribution of composite (two-string) states in the intermediate channels of the four-point scattering processes in Anti-de Sitter space were identified. By means of the study of Maldacena AdS/CFT holographic description of the processes in AdS spacetime the factorization properties of the scattering amplitudes were analyzed.

The CPT group of the Dirac field ²⁸

By using the standard representation of the Dirac equation it was shown that, up to signs, there exist only two sets of consistent solutions for the matrices of charge conjugation (C), parity (P), and time reversal (T). In both cases, $P^2 = -1$, and then two successive applications of the parity transformation to spin 1/2 fields necessarily amounts to a 2 rotation. Each of these sets generates a non abelian group of sixteen elements, G1 and G2, non isomorphic subgroups of the Dirac algebra. G1 is isomorphic to $D8 \times Z2$, where $D8$ is the dihedral group of eight elements (the symmetries of the square); while G2 is isomorphic to a certain semidirect product of $D8$ and $Z2$. On the other hand, the corresponding quantum operators for C, P, and T generate a unique group G, called the CPT group of the Dirac field, isomorphic to $Q \times Z2$, where Q is the quaternion group. The matrix groups were given in the Weyl and Majorana representations.

Classical limit of the scattering of Dirac particles by magnetic fields²⁹

The relativistic quantum scattering of charged fermions with a solenoidal magnetic field was studied. The analysis was done in the frame of the perturbation theory with free particle asymptotic states. The classical limit of the resulting cross section was analyzed, finding a consistency with the well known Aharonov-Bhom result, that corresponds to the zero radii limit of the solenoid. The large solenoid radii limit, situation that corresponds to the interaction with a constant and uniform magnetic field was also studied.

Clifford algebras and spinors³⁰

The general classification of real and complex Clifford algebras of finite dimension was presented. The naturality of this classification and some applications to the spinor theory was discussed.

The Thirring-Wess model revisited: a functional integral approach³¹

In order to obtain the functional integral bosonization of the Thirring-Wess model with an arbitrary regularization parameter, the Wess-Zumino-Witten theory was considered. By decomposing the Bose field algebra into gauge-invariant and gauge-noninvariant field subalgebras, the local decoupled quantum action was obtained. The isomorphism between the QED2 (QCD2) with broken gauge symmetry by a regularization prescription and the Abelian (non-Abelian) Thirring-Wess model with a fixed bare mass for the meson field was established.

Matrix models and Quantum Hall effects³²

The matrix model proposed by Polychronakos that is supposed to realize Susskind conjecture and that establishes a one-to-one correspondence between non-commutative Chern-Simons theories and Laughlin's states was reviewed. Some issues related to gauge invariance and the physical properties of observable charges and currents were questioned.

Consistent discretization of constrained theories³³

Consistent discretization of the Gambini-Pullin canonical formalism to treat constrained theories in Lorentz signature space-times was presented. In this way, constraints and evolution equations can be solved simultaneously up to small deviations proportional to the step of the discretization.

Final Remarks

The First Latin American Workshop on Phenomenology of the Fundamental Interactions was held at Oaxtepec - México in December 1990. At that time, Roberto Peccei from UCLA was invited to present the summary of the meeting. In the Proceedings one reads as his final sentence: "Phenomenology is alive in Latin America". We are sure that accordingly, we can end our summary of the Workshop in Buenos Aires by stating: Phenomenology of the Fundamental Interactions has certainly grown in Latin America. It has a healthy life and deserves a long life.

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1. The Lectures of the School by Massimiliano Grazzini; Zoltan Kunszt; Fernando Barreiro; Carlos Wagner; Jose Bernabeu; Marcela Carena; Hugh Montgomery; Darien Wood and Carlos Hojvat can be obtained in <http://www.giambiagi.df.uba.ar/>
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